Erbium Doped Fiber Laser

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May 19, 2018

Abstract

An Erbium doped fiber laser was built and characterized. Two fiber Bragg gratings form the Fabry-Perot cavity of the laser. It is shown that applying stress on one of these gratings changes it's effective wavelength, proportionally. Finally, we showed that changing the pump current, varies the laser optical power linearly. The built laser was characterized to a pump current threshold of $P_{th} = 50.85\ mA$ and an efficiency of $\eta = 0.012\ mW/mA$.

1 Introduction

Fiber lasers have become one of the most important developments in the laser industry due to several advantages over rod or gas lasers such as their high optical gain, high beam quality, small size and low cost of ownership, making them well suited for industrial and technological applications.

1.1 Laser

The experiment reported here is used to characterize a fiber laser based on a Fabry-Perot cavity using two fiber Bragg gratings with a mismatch in the Bragg wavelength. Reducing this mismatch by stretching the grating results in laser emission which can be analysed in terms of threshold and slope efficiency [1].

The laser uses a pump LED with a wavelength of $980nm$ and outputs at a wavelength of approximately $1550nm$, using two wavelength division multiplexers to separate these wavelengths.

The fiber laser can be caracterized in terms of pump threshold, P_{th}, which is defined as the minimum pump current required for lasing action, and laser efficiency, η_s, defined as the slope of laser output versus pump current above the threshold.

This experiment consists of firstly aligning the fiber Bragg gratings' wavelengths and then varying the amount of pump current and observing the behaviour of the laser output power. Through this measure, we should be able to calculate the two variables defined above.

1.2 Bragg Grating

One of the most important elements of this experiment are the two fiber Bragg gratings that form the laser cavity. This devices are formed by a periodic variation of the fiber's core refractive index. In order to impose this perturbation, a phase mask is commonly used together with a UV laser beam. A prerequisite for using this approach is to have photosensitive core media. To fulfil this, the fiber is usually doped with germanium and, if needed, hydrogen diffusion can be used to improve photosensitivity. The phase mask has a surface relief structure which is chosen to minimize the zero order refracted beam and maximize the ± 1 orders giving rise to a spatially modulated UV field with a period half of the period of the mask's grating.

The obtained geometry of the index perturbation is sinusoidal and of the form,

$$n(z) = n_0 + \Delta n \cos\left(\frac{2\pi z}{\Lambda}\right) \quad (1)$$

where n_0 is the average refractive index of the

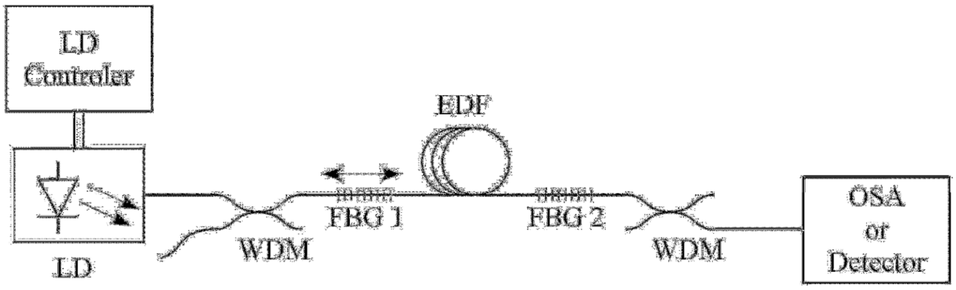

Figure 1: Experimental setup - available in [1].

fiber's core, Δn is the induced perturbation, z is a distance along the core's axis and Λ is the spatial period of the modulation (half the mask grating's period). For this modulation, it can be seen that the Bragg wavelength of the grating is,

$$\lambda_B = 2n_{eff}\Lambda \tag{2}$$

where n_{eff} is the effective index of the propagating mode. Thus, changing the spatial period by stretching the fiber grating, changes the resonant wavelength and thus impacts the behaviour of such a laser as defined above.

2 Experimental Setup

The experimental setup consists of:

- Laser Diode used for optical pumping;
- Two WDMs to separate the pump light from the emission;
- Erbium doped fiber with losses of 14dB/m at 980nm;
- Two fiber Bragg gratings used as mirrors in the optical cavity;
- Optical spectra analyser (OSA) to measure the spectrum of the laser;
- Powermeter in the place of the OSA to measure the power of the laser.

The setup is shown in Fig. 1. The light emitted by the laser diode at 980 nm passes through the first WDM and travels through the first FBG and into the Erbium doped fiber. On the other end of the fiber is the second FBG that works as an output mirror, having a coefficient of reflection of less than 100% in order to reflect most of the light back through the fiber and thus form the laser cavity along with the first FBG. A second WDM separates the light formed in the fiber laser from the pump light, dispersing this last one. Finally, the OSA recieves the laser light and analyses it's spectrum. If a powermeter is used, we can measure the power of the laser output. Since the two FBG's have slightly different resonant wavelengths, there will not be any lasing action unless the first FBG is stretched thus changing it's λ_B.

This setup requires the FBG to be glued on each side of a manual high precision stage to measure the amount of stretching. However, if too much tension is applied on the FBG, the fiber can break, which happened several times during the experiment. This sometimes requires a new grating to be spliced onto the fiber if it broke too close to the last one, delaying the experiment. Thus great care should be put in stretching the fiber gently.

Another problem that could arise, still related to the FBG, is that if the fiber is not well secured on the precision stage, it can slide inside the protection, thus rendering our stretching inefficient since only the protection is being stretched. To fix this problem, the protection must be removed and the cladding should be glued directly onto the platform.

3 Results and Discussion

The first step towards characterizing the built fiber laser, is finding the exact stretching of the grating that overlaps the two Bragg wavelengths. Since, in our case, the gratings had the same spatial period, we expect the rest state of the grating to provide the

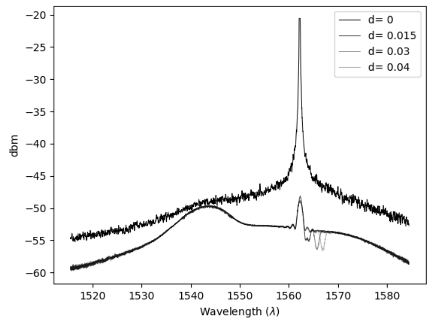

Figure 2: OSA spectrum as a function of grating stretch.

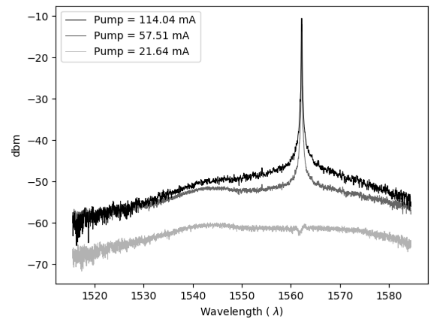

Figure 3: OSA spectrum obtained for different pump powers and aligned Bragg wavelengths.

matching wavelength and thus the highest peak in the power spectrum.

As can be seen in Fig. 2, the results match our expectation, since for $d = 0\mu m$, the spectrum has the highest peak, reaching approximately $-20dBm$. For higher stretching values, the main peak is reduced and subsequent negative peaks show that one of the Bragg gratings is reflecting and the other is transparent in that wavelength, reflecting in a different one, thus, the two Bragg wavelengths are not aligned. These secundary peaks can also show to what wavelength the Bragg grating is being tuned. Observing the graph shows us that, as expected, by stretching the grating (and thus increasing Λ), we are moving the Bragg wavelength to higher values.

Having found the alignment of the wavelengths for $d = 0\mu m$, we can now leave the grating at that position and vary the current of the pump, measuring the obtained spectrum and observing the behaviour of the laser peak.

From the data in Fig. 3, we can see that for a pump current of $21.64mA$, there is no laser action since this value is below the pump threshold, P_{th}. However, when we raise the current to $57.51mA$, we see that we are operating above P_{th}, since we can now see a peak in the OSA spectrum. Finally, when raising the pump current further, we can see that the peak becomes more intense, since we are injecting more power.

This last assumption can be verified by changing the OSA for a powermeter and observing the relation between pump current and measured optical power. From Fig. 4, we can see that this parameter shows the expected linearity on the pump current.

We can now determine the laser characterization parameters, the optical power slope, which is a measure of the efficiency of the laser and the pump current threshold, P_{th}. By taking a linear fit of the data in Fig. 4, excluding the first point, which has a pump power below the threshold, we obtained a slope of $\eta = 0.012mW/mA$ and a threshold of $P_{th} = 50.85mA$, available in Tab. 1. We can thus say that for a minimum pump current of $50.85mA$, the laser has an efficiency of $0.012mW$ of optical power per mA of pump current.

P_{th} (mA)	m (mW/mA)	b (mW)	r^2
50.85	0.012	−0.627	0.989

Table 1: Linear fit parameters.

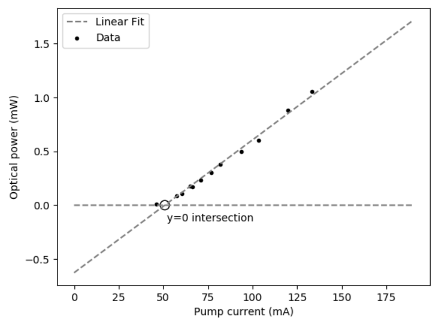

Figure 4: Optical power for different pump power values.

4 Conclusions

In this laboratory work, we showed that, by using two fiber Bragg gratings, one can build a Fabry-Perot cavity and use a pump LED to achieve laser action.

Stretching such a grating, effectively changes it's spatial period and thus the Bragg wavelength. It is showed that this displacement increases the Bragg wavelength accordingly.

We observed that the output power of the laser varies linearly with the pump current applied. The laser was shown to achieve lasing action with a pump current threshold of $P_{th} = 50.85mA$ and an efficiency of $\eta = 0.012mW/mA$.

References

[1] Paulo V. S. Marques, Manuel B. Marques, and Carla C. Rosa. Advanced experiments with an erbium doped fiber laser.